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Transmitted herewith for filing is the Patent Application of:

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and Xiaogang Wang

For: System and Method to Verify Availability of a Back-Up Secure Tunnel

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Enclosed are

37 pages of specification, including 45 claims, plus 11 sheets of drawings.

X An assignment of the invention to International Business Machines Corporation, Armonk, New York 10504.

A certified copy of a/an application.

X Declaration and Power of Attorney.

PTO-1449 & references

x A return post card

Other:

Filing Fee Calculation (For Other Than Small Entity)

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**SYSTEM AND METHOD TO VERIFY
AVAILABILITY OF A BACK-UP SECURE TUNNEL**

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Cross Reference to Related Applications

This patent application is related to, and contains common disclosure with, co-pending and commonly assigned patent application "Apparatus, Method and System for Secure Tunnel Ping and Message Format for Use Therein", serial number 09/438,119, filed November 10, 1999; "System and Method to Monitor if an Active IPsec Tunnel has Become Disabled", serial number (attorney docket number RAL9-1999-0037 US1); "System and Method to Determine Connectivity of a VPN Secure Tunnel", serial number (attorney docket number RAL9-1999-0038 US1); and "System and Method for Conversion of an ICMP Ping to an IPsec Ping via a Proxy-Ping Function", serial number (attorney docket number RAL9-1999-0035US1). The co-pending patent applications are hereby incorporated by reference into this description as fully as if here represented in full.

Background Of The Invention

The present invention relates to improvements in the systems and methods for communicating in an environment including at least one secure tunnel (such as is sometimes referred to as Internet Protocol Security or "IPsec" herein and in the industry and its standards activity).

Communications systems involve a variety of devices which are connected to a data transmission network, often through a variety of conventional devices such as routers, switches and other components. As the networks have become larger, incorporating local area networks (LANs) and wide-area networks (WANs), these networks have become more complex and involve an increasing number of components. One of the largest networks is referred to as the Internet, a constantly-changing communications network including a large number of interconnected network devices or workstations.

In addition, many companies are now applying Internet technologies to build private Intranets, enabling users in an organization to go beyond electronic mail and access critical data through web browsers. While Internet traffic is currently composed primarily of text, graphics, and images, this traffic is expected to expand in the near term to include more bandwidth intensive audio, video, voice, and multi-media applications.

As applications proliferate and demand ever greater shares of bandwidth at the desktop and as a total number of users continues to grow, the pressure for increased bandwidth will continue to grow at the desktop, the server, the hub, and the switch. Organizations will need to migrate critical portions of their networks to higher bandwidth technologies, such as Gigabit Ethernet, Fast Ethernet, Gigabit Token-Ring, and High Speed Token-Ring.

Successful communications requires that each message be properly addressed within the communications system and that each link in the communications system be connected to the system and perform properly. If any of the links fail, communications through the failed link will not be successful. When communications through the system have failed, it is necessary to isolate the

problem so it can be resolved, a process which involves testing the components, either individually or in groups.

One method of testing a communications system to determine if it is properly connected and performing is called a "ping". A ping is a message sent from a first network device and addressed to a second network device with the request that a responsive message be returned from the second network device to the first device, indicating that both network devices and the intervening network devices are properly connected to the network and that each is working appropriately.

A ping is also used in testing large and complex networks. It is particularly useful for testing the network in portions. Thus, when the entire network is not properly working pings may be used to isolate the problem. In essence, a portion of the network can be tested and determined to be operating properly, indicating that any problem in the larger network must be located elsewhere.

Communications on the Internet presents additional problems because of the size of the network and because communications are not handled in a uniform manner -- a first packet between two devices may be sent over one route and a completely different path may be used for a second packet, even when both packets are part of the same message. Furthermore, the Internet is inherently unsecure. As security techniques are defined to add security to the Internet, these techniques often conflict with the techniques (such as the "ping" testing methods) which have been in common use.

As organizations such as the Internet Engineering Task Force (IETF) define techniques for reducing the security exposures of Internet communications, security concepts such as IP security (IPSec) have been proposed. IPSec is a developing standard for security at the network or packet

processing layer of network communications. Earlier security approaches inserted security at the application layer of the communications model. IPSec is especially useful for implementing virtual private networks (VPNs) and for remote user access through dial-up connection to private networks. A big advantage of IPSec is that security arrangements can be handled without requiring changes to individual user computers. IPSec provides two choices of security service: Authentication Header (AH), which allows authentication of a sender of data and Encapsulating Security Payload (ESP) which supports both authentication of the sender and encryption of the data as well. The specific information associated with each of these services is inserted into the packet in a header that follows the IP packet header. Separate key protocols can be selected, such as the ISAKMP/Oakley protocol.

One feature of IPSec includes secure tunnels, in which a single logical tunnel is limited to communication of messages from a single source address to a single destination address and which may require other specific security features defined for communication between network devices. A secure tunnel in such communications systems inherently provides a limited, one-way communications path because its definition allows only messages from a single source to a single destination, so that a return message from the original destination back to the original source cannot use the same secure tunnel as the message going the other way, but such return message must use a different path such as a different secure tunnel with its own security requirements.

Tunneling or encapsulation is a common technique in packet-switched networks. It consists of wrapping a packet in a new one. That is, a new header is attached to the original packet. The entire original packet becomes the payload of the new one. In general, tunneling is used to carry

traffic of one protocol over a network that does not support that protocol directly. For example, NetBIOS or IPX can be encapsulated in IP to carry it over a TCP/IP wide area network (WAN) link. In the case of IPSec, IP is tunneled through IP for a slightly different purpose, i.e., to provide total protection, including the header of the encapsulated packet. If the encapsulated packet is encrypted, an intruder cannot figure out the destination address of that packet. Without tunneling the intruder could. The internal structure of a private network can be concealed in this manner.

A notable advantage of IP tunneling is the possibility to exchange packets with private IP addresses between two intranets over the public Internet, which requires globally unique addresses. Since the encapsulated header is not processed by the Internet routers, only the end points of the tunnel (the gateways) need to have globally assigned addresses; the hosts and the intranets behind them can be assigned private addresses. As globally unique IP addresses are becoming a scarce resource, this interconnection method gains importance.

IPSec can be configured to create tunnels in two modes:

1. Tunnel mode - in which the protocol data unit (PDU) is encapsulated within another IP frame and an outermost IP address is added. This address is the address of the tunnel termination device.
2. Transport mode - in which the PDU is not encapsulated and the existing (outermost) IP address is used. This address is the address of the tunnel termination device.

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The present invention applies to tunnel mode. Note that in IPSec terminology, the word tunnel is used to describe both a mode of operation, i.e., tunnel mode (a new header is created to encapsulate the original IP frame), or transport mode (no new header is created).

5 It is necessary to have certain information in order to use a secure tunnel: for example, the configuration/policy for IPSec devices may require a "legal address", a security protocol indicator (also known as an SPI value) and a valid key before an originating device can send frames through a secure tunnel to a destination device.

Prior art secure communications systems have disadvantages and limitations and constructing a message for providing a ping in a system of secure tunnels is far from a simple process and may depend on information which is hard to acquire and difficult to use. Furthermore, the entire concept of a "ping" message in a secure tunnel environment such as the IPSec proposed by a standards organization may be difficult to implement, in view of the construction and operation of the secure tunnels which have the effect of limiting communication and requiring strict adherence to certain communications protocols.

15 The above-referenced co-pending, commonly assigned patent application "Apparatus, Method and System for Secure Tunnel Ping and Message Format for Use Therein" provides a "ping" method for testing a secure communication system. During the life of an IPSec tunnel, a variety of problems may occur to disrupt the connectivity of the tunnel. Within the IPSec standard, there is no "keep alive" or "heart beat" protocol to detect that a tunnel is no longer functioning, thus there
20 is no method at the network layer that can detect this.

Summary of the Invention

The present invention overcomes the disadvantages and limitations of the prior art communications systems, particularly in the secure tunnel environment. More particularly, the present invention provides a method and system for determining if an existing IPsec tunnel that is not actively used and that has been configured as a back-up tunnel between network elements in a secure communication system is still active and, if not, sending a notification to a network administrator. Such an invention has particular applicability in a secure tunnel system of the type described in proposed standards such as the IPsec protocol.

The present invention has the advantageous effect that it facilitates testing of the secure tunnel capability of a network, in addition to testing the physical connections of the network.

The present invention has the advantageous feature that it may be used without regard to the configuration of the destination device. In fact, the destination device may not even realize that a "ping" message has passed through it and returned to the device originating the message.

The present invention has the benefit that knowledge of the outgoing message handling procedures or protocols of the destination device is not required on the part of the originating machine. This is because the destination device passes the "ping" message back to the originating device through the destination device's normal handling of outgoing mail, such as an IP protocol stack.

The present invention has the advantage that the return message from a destination device passes through the secure tunnels, for example, of the type referred to as the IPSec tunnels proposed by the IETF.

Other objects and advantages of the present invention will be apparent to those skilled in the relevant arts in view of the following detailed description of the preferred embodiment, taken in conjunction with the appended claims and the accompanying drawings.

Brief Description of the Drawings

The invention is better understood by reading the following detailed description of the invention in conjunction with the accompanying drawings, wherein:

Figs. 1A - 1B illustrate IPSec back-up tunnels between the same network elements as are used for the active tunnel and between different network elements than are used for the active tunnel.

Fig. 2 illustrates an embodiment of a system configuration of the invention.

Fig. 3 illustrates the processing logic to determine if an IPSec back-up tunnel is usable.

Fig. 4 illustrates a simplified systems configuration for a secure communications environment of the present invention, having two one-way tunnels between two network devices.

Fig. 5 illustrates a logical representation of the system of Fig. 3, with added detail on the content of messages sent between the two devices shown.

Fig. 6 illustrates a logical representation of a portion of the system of Fig. 4 showing an originating network device and the message content sent by the network device in practicing the present invention.

Fig. 7 illustrates a logical representation of a portion of the system of Fig. 4, showing an originating network device with the returned message from a destination network device.

Fig. 8 illustrates processing logic for handling a returned IPsec message.

Fig. 9 illustrates a representation of the message sent from the originating network device to the destination network device to practice the present invention.

Fig. 10 illustrates an alternate embodiment of the present invention for use in an Internet and firewall environment of an alternate network.

Fig. 11 illustrates a logical view of selected fields from the Tunnel Definition data base.

Detailed Description of the Invention

The following detailed description of the present invention is provided as a detailed, enabling teaching of the present invention in its best currently-known embodiment. Those skilled in the relevant arts will recognize that many changes can be made to the embodiment described while still obtaining the beneficial results of the present invention. It will also be apparent that some of the desired benefits of the present invention can be obtained by selecting some of the features of the present invention without using other features. Accordingly, those who work in the art will realize that many modifications and adaptations to the present invention are possible and may even be

desirable in certain circumstances and are a part of the present invention. Thus, the following description is provided as illustrative of the principles of the present invention and not in limitation thereof, since the scope of the present patent is defined by the claims.

IPSec (IP Security) is an extension to the Internet Protocol (IP) protocol stack which provides secure tunnels between the IP stacks in two network elements. The Internet Engineering Task Force (IETF) has a number of draft standards supporting IPSec; the overview architecture is found in Request for Comments (RFC) 2401, "Security Architecture for the Internet Protocol".

This invention defines a method to determine if an existing IPSec Tunnel that is not actively used and has been configured as a back-up tunnel between the network elements has stopped working. Since the tunnel is logical, rather than physical, a method using IPSec itself must be used (i.e., the physical interface may be up and passing traffic, but the logical tunnel formed by IPSec can be down).

IPSec, in tunnel mode, encapsulates an IP header, the inter PDU, within a new IP header and sends the frame to the upper IP stack for decapsulation. Filter or access controls define what frames (by protocol type, IP address, etc.) are allowed to flow through the tunnel. These filter/access controls (called configurations or policies) are set as restrictive as possible in an attempt to prevent unauthorized traffic from flowing through the tunnels. Currently, unless the IPSec filter/access controls at the originating endpoint are explicitly configured to allow the ping out of the tunnel, it is not desirable to allow the ping to flow through the tunnels. Thus, a new method to accomplish the same purpose as a ping is needed. Such method is described in co-pending patent application

"Apparatus, Method and System for Secure Tunnel Ping and Message Format for Use Therein".

The present invention utilizes the IPSec Tunnel Ping although this is not essential to the present invention if an alternative methodology to test the IPSec tunnel is available.

5 The need for having an unused back-up tunnel may not be readily apparent. An owner of a private network may contract with two Internet Service Providers (ISPs) for access to the Internet. All traffic may be tunneled over one ISP. If there is a failure in the logical tunnel in the main ISP, the administrator of the private network would move to the back-up ISP. The back-up ISP tunnel must be logically up to do this quickly. The cost of having a back-up tunnel operational, but not used, is small. As illustrated in Figs. 1A - 1B, a back-up tunnel can be through different paths (interfaces) between the same network equipment (Fig. 1A) or it can be between different network equipment (Fig. 1B).

15 The present invention solves the problems of how to associate the back-up link with the primary link, and how to verify the connectivity of the back-up link itself. In a robust network configuration, back-up links are available if needed. For IPSec tunnels, these links are logical, i.e., the physical port that a link is on may be up, but the logical IPSec link can be unavailable. In some networks, the administrator will "bring up" the primary tunnel and a back-up tunnel simultaneously. No data traffic is sent through the back-up tunnel. During the life of the back-up IPSec tunnel, a variety of problems can occur to disrupt the connectivity of the tunnel. Within the IPSec standard, there is no association of a primary link with its back-up link; and no
20 "keep alive" or "heart beat" protocol to detect that a tunnel is no longer functioning. Thus, there is

no method at the network layer that can detect that the back-up tunnel is no longer available if it is needed.

The following description describes a system and method to associate a primary link with its back-up link and then to detect that an IPSec back-up tunnel's connectivity has been lost. This invention uses the IPSec tunnel ping described in the co-pending patent application "Apparatus, Method and System for Secure Tunnel Ping and Message Format for Use Therein". In one preferred embodiment, the back-up tunnel verification method is initiated from either:

1. a command given at a console interface on the network element that forms the tunnel (A in Fig. 2);
2. initial configuration of the network element that forms the tunnel (B in Fig. 2); or
3. a network management entity, i.e., the network administrator (C in Fig. 2).

The results of the method is returned to either the console interface and/or a network management entity, C in Fig. 2. C can be any network management system that accepts unsolicited notifications, i.e., Simple Network Management Protocol (SNMP) traps. The results can also be stored locally, i.e., in a log file or in a Management Information Base (MIB).

Note that in Fig. 2, for illustrative purposes, the IPSec "tunnel" between two network elements is composed of two unidirectional tunnels. The solid lines originating at A, B and C indicate the flow which instantiates the function and the corresponding dashed lines indicate the results.

Upon instantiation of the back-up tunnel verification function and using the IPsec Tunnel Ping (ITP), the function periodically verifies the connectivity of the back-up IPsec tunnel with the following algorithm (or a variant thereof). For purposes of illustration, the implementation abstract of the Back-up Tunnel Verification function (BTV) is given by the following parameters:

5	BTV	the command, e.g., Back-up Tunnel Verification;
	id	the identification of the primary tunnel;
	time_to_run	the time that the back-up verification function will be active;
	time_between	the time to wait between each verification attempt;
	number_of_failures	the number of consecutive failures of connectivity attempts required to determine that the tunnel is no longer available;
	who_to_tell	the entity to which the notification should be sent, e.g., the console, a receiver of SNMP traps, a MIB table, a log file, etc.; and
	bytes	the payload size of the connectivity test packet.

A similar command can be envisioned to stop the function before the time has expired, i.e.,
15 BTV STOP. However, in the preferred embodiment, the time_to_run is set to the tunnel validity period. In one implementation, the entity is the console and/or the IP address of the SNMP network management station to which an SNMP trap will be sent followed by the SNMP community name to send the SNMP trap. The SNMP trap will contain the tunnel ID and the tunnel Index (index into the IPsec Tunnel Table). In other implementations, the entity could be any entity which can receive
20 an unsolicited notification such as an e-mail address.

The above parameters, although not needed to instantiate the Back-up Tunnel Verification function, are provided for flexibility and future extensions. In the preferred embodiment, this function would automatically be instantiated when a "back-up" tunnel was configured, i.e., unless explicitly instantiated, the function parameters would default to the following:

5 time_to_run: the validity period of the back-up tunnel;

 time_between: 5 seconds;

 number_of_failures: 1;

 who_to_tell the console and/or all configured SNMP trap receivers, i.e., network
 management entities; and

 bytes: 0 (no extra bytes typically needed).

Fig. 3 illustrates the processing logic of the Back-up Tunnel Verification function. Processing starts from either start block 300 or start block 302. Start processing logic block 300 represents a start from a console or initial configuration. Start processing logic block 302 is started by a network management entity. From either start processing logic block, processing continues as indicated in logic block 304 by obtaining the back-up general policy name via a pointer to the back-up tunnel policy from the primary tunnel policy. In decision block 306, a test is made to determine if an IKE or a manual key tunnel is in use. If it is an IKE tunnel, then in decision block 308, a test is made to determine if phase II of the IKE process is up. In phase I, two ISAKMP peers establish a secure, authenticated channel with which to communicate. This is called the ISAKMP security association. In phase II, a "Quick Mode" is used to derive keying material and negotiate shared

policy for non-ISAKMP security associations. If IKE phase II is not up, then, in logic block 310 a request is made for the IKE (phase I) process to generate a phase II connection. Processing then loops back to decision block 308. If in decision block 306, a manual key tunnel is indicated, then processing continues in logic block 312 with obtaining the back-up tunnel identification. Likewise, in decision block 308, if an IKE phase II connection has been generated, processing continues in logic block 312 in which the back-up tunnel identification is obtained. Next, in decision block 314, a test is made to determine if the time_to_run has expired or if a stop has been received. If the answer is yes, then processing ends in termination block 318 with the results returned to the caller (i.e., who_to_tell parameter). If the time_to_run has not expired and a stop has not been received, then in logic block 316, a wait period is entered based on the time_between parameter. The ITP of size "bytes" is then sent through the tunnel ID, as indicated in logic block 320. A test is made in decision block 322 to determine if the ITP has been returned. If it has been, then the failure counter is reset, as indicated in logic block 324. If the ITP has not been returned, then the failure counter is incremented as indicated in logic block 326. From either logic block 324 or logic block 326, processing continues in decision block 328 with a determination of whether or not the failure count exceeds the number_of_failures parameter. If it does, then processing ends in termination block 330, with results returned to the caller (i.e., who_to_tell parameter) that the back-up tunnel is not operational. If the failure count does not exceed the number_of_failures parameter, processing loops back to decision block 314, where a test is again made to determine if the time_to_run has expired or a stop has been received.

the secure tunnels. Typically, a given tunnel, such as tunnel 32 will define a unidirectional path in the direction of the arrow 32A, that is, allowing packets to pass from the first device 10 to the second device 20 (but not in the other direction, from the second device 20 to the first device 10), by requiring that the source of the packet to be the address of the first device 10 and requiring the destination to be the address of the second device 20 in order to use the tunnel 32. A tunnel has a Security Association which defines a data structure that describes which transformations are to be applied to datagrams that use the tunnel and how the transformations are to be applied. An SA is a unidirectional logical connection between two IPsec systems. An arbitrary 32-bit number called the Security Parameter Index (SPI), the destination address and the IPsec Protocol Identifier are used to uniquely identify each SA. The SPI is assigned to an SA when the SA is negotiated, and is used to identify different SAs with the same destination address and security protocol..

Each packet or datagram must have the appropriate Security Parameter Index or SPI (shown here as SPI_1) and key(s) (shown here as Key_1) in order to use the first tunnel 32. The path for a packet from the second device 20 to the first device 10 is shown as a second tunnel 34, operating in the direction of the arrow 34B and using SPI_2 and Key_2.

The first and second tunnels 32, 34 may be either physical or logical tunnels, and a plurality of tunnels may be associated with each IPsec device. Multiple tunnels may be defined between the same tunnel termination points, but each tunnel has a unique SPI and a unique key for encryption, decryption and authentication. Multiple keys may be associated with a secure tunnel. A tunnel provides for a one-way communication path between a sender and receiver.

An IPSec tunnel termination device such as the first network device 10 must have the correct addresses for the source and the destination, the correct SPI value and the correct key(s) for encryption and decryption to properly create a packet or datagram or message for sending and for deciphering (for receiving) a packet. The present invention recognizes that the information for the tunnel is unique for each direction of the tunnel, as shown in Fig. 4, and as indicated in Fig. 11 depicting a logical portion of the tunnel definition database. The present invention also recognizes that a tunnel definition database (15, 25) which is stored in each IPSec device contains the necessary information, at the conclusion of the Internet Key Exchange (IKE) process, to enable a secure ping message to be sent from a first IPSec device to a second IPSec device on a first IPSec tunnel and returned from the second IPSec device to the first IPSec device on a second IPSec tunnel. The IKE process is used to establish the tunnels and tunnel definition database, as established in the documents setting up such communication protocols, such as those established by the IETF. Request for Comments (RFC) 2401, "Security Architecture for the Internet Protocol" and Request for Comments (RFC) 2409, "The Internet Key Exchange (IKE)," both published in November 1998, are hereby incorporated by reference. Fig. 11 depicts a logical view of selected fields for the tunnel definition database. As those of ordinary skill in the art will recognize, the tunnel definition data bases (15, 25) contain many other fields in addition to those shown in Fig. 11, which may be used with the present invention.

Still referring to Fig. 4, once the IKE process has occurred and the communication information has been obtained, communications using the tunnels can be established. In order to

conduct a communication over the secure tunnels 32, 34 between the first network device 10 and the second network device 20, the first network device 10 possesses the address of the destination (second) network device 20, the address of the first network device 10, the SPI_1 and the Key_1 necessary for use of the first tunnel 32 and the information (destination address, source address, SPI_2 and Key_2) necessary for use of the second tunnel 34 for a packet returning from the second device 20 to the first device 10. The communication information is stored in a database associated with each IPSec device, that is, a database 15 associated with the first device 10 (device A) and a database 25 associated with the second device 20 (device B).

Fig. 5 illustrates the principle of the present invention directed to how to get a "ping" packet to "turn around" at the destination device 20, once it has been sent from the first device 10 using the first tunnel 32. A packet 40 is sent from the first device 10 to the second device 20 through the first IPSec tunnel 32. The packet 40 includes an outer header 42, an inner header 44 and the rest of the frame or message 46. The outer header 42 includes protocol information including the SPI_1 and the Key_1 as well as the IP address of the tunnel source device 10 (shown here for exemplary purposes as 1.1.1.1) and the IP address of the tunnel destination device 20 (shown here for exemplary purposes as 2.2.2.1). The inner header 44 includes protocol information for the return message, that is, the header for use when the original destination system sends the "ping" message back to the original source system. The inner header 44 includes the protocol information for the return message (from the second device 20 as source to the first device 10 as destination, using the IP address of the second terminal, 2.2.2.1, as the source address and the IP address of the first device

10, 1.1.1.1 as the destination address) along with the SPI_2 and the Key_2 for the second tunnel. Notice that the source and the destination addresses are inverted or reversed between the outer header 42 and the inner header 44 so that the packet will turn around at the second device 20 for the return trip to the first device 10 via second secure tunnel 34. The rest of the frame or message 46 is included in the packet 40.

When the packet 40 is received at the second device 20, the outer header 42a is discarded and the remainder of the packet 40 (the inner header 44A and the rest of the frame 46A) is treated as usual at the second device 20 by putting it on an IP protocol stack, which is then handled by an IP routing function 26. The IP routing function 26 sees the remainder of the packet 40 (the inner header 44a and the rest of the frame 46A) as an outgoing message, addressed to the first device 10 from the second device through the second secure tunnel 34 back to the first device 10.

Fig. 6 illustrates the packet 40 being sent from the first device 10 to the second device 20 (as shown in Fig. 5) through the first IPSec tunnel 32. As shown in Fig. 6, the packet or message 40 includes the outer header 42 and the inner header 44 and the rest of the frame 46, with the inner header 44 and the rest of the frame 46 making up a return message portion 48. The return message portion 48 is pre-encapsulated with the SPI_2 and the Key_2 (not SPI_1 and Key_1), with the SPI_2 and Key_2 being the specific instances of the Security Parameter Index and encryption key that the second terminal 20 would use for return communications (rather than the SPI_1 and encryption Key_1) which the first device uses in its normal outgoing communications. When the second device 20 receives the packet 40, it decapsulates the packet 40 and removes the outer header 42, much like

when a person removes the envelope in which postal service mail is mailed. The second device 20 will not decapsulate the inner header 44 since the inner header address is not destined to the second device 20. The decapsulated packet will then be delivered to the IP protocol stack and the IP routing function 26 which will send the return message portion 48 of the message back to the first device 10 and accomplish the round trip of the IPSec Tunnel Ping (ITP).

Fig. 7 illustrates the return message 48, as received by the first device 10 from the second terminal 20 through the second secure device 34. When the return message 48 is received by the first device 10, it is desirable that the message be recognized as a returned "ping" message and discarded. This recognition depends on two attributes of the IPSec message: that it contains a nested IP header within the IPSec packet and that it includes one or more values in the nested IP header that can be made unique. The constructed return message 48 includes a header 48A (the inner header 44 from the original packet 40 as described in connection with Figs.4-6) and an inner protocol data unit (PDU) 49 with a third encapsulated IP header, including a source address 49A, a destination address 49B and a payload 49C. In the preferred embodiment of the invention, the source address 49A is set to an illegal value such as x'FFFFFFFF' and the protocol type is set to 50. While the payload 49C is not defined by the current system, it may include a sequence number and a time stamp, so that the system can determine which ping is being returned and when it was originally sent so that the time period for the ping can be determined.

Fig. 8 illustrates the processing logic for handling a returned IPSec message 48 at the first network device 10. The inbound frame 48 flows into an IPSec function box 60 which includes an

IPSec decapsulation (decryption and removal of header 48A) at logic block 62. Next, at decision block 64, the SPI (from the header 48A) is tested to see if it is a defined protocol (such as 50 or 51. If the result is "yes" at decision block 64, then at decision block 66, a test is made to determine if the destination address is the same as the address of the first network device. If yes, the process continues at decision block 68 where the source address 49A in the third encapsulated IP header is tested for the "illegal value" of x'FFFFFFFF'. If the source address 49A for the inbound frame is not the illegal value, then processing control returns to logic block 62 to handle the next inbound frame. If the source address 49A for the inbound frame is the illegal value of x'FFFFFFFF', then the "receive ITP function" is executed in logic block 69, indicating that an IPSec ping has been successfully received back from the second device, and that the second device and the intervening network, including the secure IPSec tunnels 32, 34 are functioning properly.

If the result of the test in decision block 64 is "no", indicating that the protocol type is not proper (50 or 51 for IPSec), then control proceeds to decision block 70 where the destination address is tested to see if the message is addressed to the first device 10 with its Internet Protocol (IP) address. If the answer is yes in decision block 70, then the inbound frame is put on the local queue function at logic block 72, that is, the message is something other than an IPSec message or a IPSec ping message. If either decision block 66 or decision block 70 yields a no answer, indicating that an inbound frame is not addressed to the first device 10 with its IP address, then the inbound frame is handled by a forwarding function at logic block 74 to send it to the proper network device.

Fig. 9 illustrates the entire message 40 as originally formulated by the first device 10 to begin the process of the ping of a secure tunnel as described in connection with the present invention. The entire message 40 includes the return message 48 which, in turn, includes the innermost PDU 49 which includes the third IP header 49A, 49B and the payload 49C, as discussed above. The returned portion 48 is encrypted with the Key_2 and the SPI_2 (which would normally be used by the second device 20), and then the so-encrypted returned message 48 plus the header 42A are encrypted with the Key_1 and the SPI_1 of the first device, with all the encryption taking place at the first device 10.

Fig. 10 illustrates the use of the present invention in the context of an Internet system 80 with a first network 82 communicating with a second network 84 through the Internet. Associated with the first network 82 is a firewall 82A and a firewall 84A is associated with the second network 84. Each of the firewalls 82A, 84A would have associated key(s) and SPI value(s) through some key distribution system such as the Internet Key Exchange (IKE), not shown, but various methods of key distribution are well known to those involved in the art. The firewalls 82A, 84A define the secure tunnels into each network, allowing traffic (inbound messages) only from devices which are known to it and authorized by it to communicate with the respective associated networks. For the first network 82 to test the tunnels and communications between it and the second network 84, it must test the secure tunnels going both ways. That is, a message from the first network device 82 to the second network device must test the firewall 84A and the return message from the second network device 84 to the first network device 82 must test the firewall 82A on the return.

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0963079 " 030200
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The present invention can be realized in hardware, software, or a combination of hardware and software. Any kind of computer system or other apparatus adapted for carrying out the methods described herein is suited. A typical combination of hardware and software could be a general purpose computer system with a computer program that, when being loaded and executed, controls
5 the computer system such that it carries out the methods described herein. The present invention can also be embedded in a computer program product, which comprises all the features enabling the implementation of the methods described herein, and which, when loaded in a computer system, is able to carry out these methods.

Computer program means or computer program in the present context mean any expression, in any language, code or notation, of a set of instructions intended to cause a system having an information processing capability to perform a particular function either directly or after either or both of the following occur: a) conversion to another language, code or notation; b) reproduction in a different material form.

Those skilled in the art will appreciate that many modifications to the preferred embodiment
15 of the present invention are possible without departing from the spirit and scope of the present invention. For example, the present invention can be extended to systems with multiple back-up tunnels. Furthermore, the use of physical security pipes instead of logical security pipes could be used to advantage. Alternatively, a mode can be used where some of the communications spectrum is reserved for such secure pipes. Also, the "ping" of the present invention could be used where
20 details of the security of the remote network device are known, since the "ping" works without

regard to the type of hardware and software which are located at the remote end (the destination).

In addition, it is possible to use some of the features of the present invention without the corresponding use of other features. In this regard, it is possible to use a return path which is not secure to test the one-way communications of the network, and, in that case, it may not be necessary

5 to provide a doubly-encapsulated message with all the additional information necessary to provide for round-trip securing of Internet protocol security. Further, it may be desirable to provide for testing the two secure paths separately rather than together, separately using some features of the preferred embodiment. Accordingly, the foregoing description of the preferred embodiment is provided for the purpose of illustrating the principles of the present invention and not in limitation thereof, since the scope of the present invention is defined solely by the appended claims.

What is claimed is:

1. A system for verifying the availability of a back-up secure tunnel between a pair of network elements in a communications network, comprising:
 - a first network element for originating and transmitting a back-up tunnel verification test message to a second network element using the back-up secure tunnel in response to the receipt of a back-up tunnel verification test command;
 - a second network element for receiving the backup tunnel verification test message and transmitting a response back to the first network element using the back-up secure tunnel; and
 - a backup tunnel verification function logic module in the first network element for accumulating a number of failures to respond by the second network element to the backup tunnel verification tests performed during an active verification period and determining if the accumulated number of failures is less than a threshold value specified in the backup tunnel verification test command.
2. The system for verifying the availability of a back-up secure tunnel of claim 1 wherein the backup tunnel verification function logic module further determines the number of successful responses to the back up tunnel verification tests performed.

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3. The system for verifying the availability of a back-up secure tunnel of claim 1 further comprising a computer connected to the communications network and running a network management application that transmits the backup tunnel verification test command to the first network element.
 4. The system for verifying the availability of a back-up secure tunnel of claim 1 further comprising a console interface on the first network element for generating the backup tunnel verification test command.
 5. The system for verifying the availability of a back-up secure tunnel of claim 1 wherein the back-up tunnel verification function is initiated by a configuration of a network element that forms an endpoint of the back-up secure tunnel.
 6. The system for verifying the availability of a back-up secure tunnel of claim 1 further comprising two unidirectional tunnels that form the back-up secure tunnel.
 7. The system for verifying the availability of a back-up secure tunnel of claim 1 wherein the communications network is a virtual private network (VPN).

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8. The system for verifying the availability of a back-up secure tunnel of claim 1 wherein the back-up secure tunnel is an Internet Protocol Security (IPSec) tunnel.
 9. The system for verifying the availability of a back-up secure tunnel of claim 8 wherein the back-up tunnel verification test message is an IPSec tunnel ping.
 10. The system for verifying the availability of a back-up secure tunnel of claim 1 further comprising a primary secure tunnel for handling data traffic between the pair of network elements.
 11. The system for verifying the availability of a back-up secure tunnel of claim 1 wherein the backup tunnel verification test command includes an identification of the secure tunnel to test, and a time interval during which a number of backup tunnel verification tests are performed.
 12. The system for verifying the availability of a back-up secure tunnel of claim 11 wherein the backup tunnel verification test command further comprises a time to wait between each backup tunnel verification test and a payload size of a backup tunnel verification test packet.

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13. The system for verifying the availability of a back-up secure tunnel of claim 6 wherein a first back-up unidirectional tunnel is used to send an Internet Protocol Security (IPSec) tunnel ping from the first network element to the second network element, and a second back-up unidirectional tunnel is used to send a response IPSec tunnel ping from the second network element to the first network element.
 14. The system for verifying the availability of a back-up secure tunnel of claim 1 further comprising a plurality of back-up secure tunnels between the pair of network elements.
 15. A method for verifying the availability of a back-up secure tunnel between a pair of network elements in a communications network, comprising the acts of:
 - originating and transmitting a backup tunnel verification test message from a first network element to a second network element using the back-up secure tunnel in response to the receipt of a backup tunnel verification test command;
 - receiving the backup tunnel verification test message from a second network element and transmitting a response back to the first network element using the back-up secure tunnel; and
 - accumulating a number of failures to respond by the second network element to the backup tunnel verification tests performed during an active verification

period and determining if the accumulated number of failures is less than a threshold value specified in the backup tunnel verification test command.

16. The method for verifying the availability of a back-up secure tunnel of claim 15 further comprising determining the number of successful responses to the backup tunnel verification test.
17. The method for verifying the availability of a back-up secure tunnel of claim 15 further comprising transmitting the backup tunnel verification test command from a network management application to the first network element.
18. The method for verifying the availability of a back-up secure tunnel of claim 15 further comprising generating the backup tunnel verification test command at a console interface on the first network element.
19. The method for verifying the availability of a back-up secure tunnel of claim 15 further comprising initiating a back-up tunnel verification function by an initial configuration of a network element that forms an endpoint of the back-up secure tunnel.

20. The method for verifying the availability of a back-up secure tunnel of claim 15 wherein the back-up secure tunnel is formed from two unidirectional tunnels.
21. The method for verifying the availability of a back-up secure tunnel of claim 15 wherein the communications network is a virtual private network (VPN).
22. The method for verifying the availability of a back-up secure tunnel of claim 15 wherein the back-up secure tunnel is an Internet Protocol Security (IPSec) tunnel.
23. The method for verifying the availability of a back-up secure tunnel of claim 22 wherein the backup tunnel verification test message is an IPSec tunnel ping.
24. The method for verifying the availability of a back-up secure tunnel of claim 15 wherein the backup tunnel verification test command includes an identification of the back-up secure tunnel to test, and a time interval during which a number of backup tunnel verification tests are performed.
25. The method for verifying the availability of a back-up secure tunnel of claim 24 wherein the backup tunnel verification test command further comprises a time to wait between each backup tunnel verification test and a payload size of a backup tunnel verification test packet.

26. The method for verifying the availability of a back-up secure tunnel of claim 20 wherein a first unidirectional tunnel is used to send an Internet Protocol Security (IPSec) tunnel ping from the first network element to the second network element, and a second unidirectional tunnel is used to send a response IPSec tunnel ping from the second network element to the first network element.

27. A computer readable medium containing a computer program product for verifying the availability of a back-up secure tunnel between a pair of network elements in a communications network, the computer program product comprising:

program instructions that originate and transmit a backup tunnel verification test message to a paired network element using the back-up secure tunnel in response to the receipt of a backup tunnel verification test command;

program instructions that receive a backup tunnel verification test message and transmit a response back to a paired network element using the back-up secure tunnel; and

program instructions that accumulate a number of failures to respond by the second network element to the backup tunnel verification tests performed during an active verification period and determine if the accumulated number of

failures is less than a threshold value specified in the backup tunnel verification test command.

28. The computer program product for verifying the availability of a back-up secure tunnel of claim 27 further comprising program instructions that determine the number of successful responses to the backup tunnel verification tests performed.
29. The computer program product for verifying the availability of a back-up secure tunnel of claim 27 further comprising program instructions that receive the backup tunnel verification test command from a network management application.
30. The computer program product for verifying the availability of a back-up secure tunnel of claim 27 further comprising program instructions that generate the backup tunnel verification test command.
31. The computer program product for verifying the availability of a back-up secure tunnel of claim 27 wherein two unidirectional tunnels form the back-up secure tunnel.
32. The computer program product for verifying the availability of a back-up secure tunnel of claim 27 wherein the back-up secure tunnel is an Internet Protocol Security (IPSec) tunnel.

33. The computer program product for verifying the availability of a back-up secure tunnel of claim 27 wherein the communications network is a virtual private network (VPN).
34. The computer program product for verifying the availability of a back-up secure tunnel of claim 32 wherein the back-up tunnel verification test message is an IPSec tunnel ping.
35. The computer program product for verifying the availability of a back-up secure tunnel of claim 27 wherein the backup tunnel verification test command includes an identification of the secure tunnel to test, and a time interval during which a number of back-up tunnel verification tests are performed.
36. The computer program product for verifying the availability of a back-up secure tunnel of claim 35 wherein the backup tunnel verification test command further comprises a time to wait between each back-up tunnel verification test and a payload size of a back-up tunnel verification test packet.
37. The computer program product for verifying the availability of a back-up secure tunnel of claim 31 wherein a first unidirectional tunnel is used to send an Internet Protocol Security (IPSec) tunnel ping from the first network element to the second network element, and a

second unidirectional tunnel is used to send a response IPSec tunnel ping from the second network element to the first network element.

38. A method for determining the identity of a back-up secure tunnel between a pair of network elements in a communications network, comprising the acts of:

obtaining a back-up tunnel policy name using a pointer to a back-up tunnel policy
from a primary tunnel policy stored at a first network element;
determining if the back-up secure tunnel is an Internet Key Exchange (IKE) tunnel;
if the back-up secure tunnel is an IKE tunnel, determining if an IKE phase II
connection between the pair of network elements has been established;
requesting an IKE phase I connection to generate an IKE phase II connection if it has
not been established previously;
generating the back-up tunnel identification when the IKE phase II connection has
been established.

39. The method for determining the identify of a back-up secure tunnel of claim 38 wherein the back-up secure tunnel is formed from two unidirectional tunnels.

40. The method for determining the identify of a back-up secure tunnel of claim 38 wherein the communications network is a virtual private network (VPN).

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41. The method for determining the identify of a back-up secure tunnel of claim 38 wherein the back-up secure tunnel is an Internet Protocol Security (IPSec) tunnel.
42. A method for determining the identity of a back-up secure tunnel between a pair of network elements in a communications network, comprising the acts of:
- obtaining a back-up tunnel policy name using a pointer to a back-up tunnel policy from a primary tunnel policy stored at a first network element;
 - determining if the back-up secure tunnel is a manually generated tunnel;
 - generating the back-up tunnel identification if the back-up secure tunnel is a manually generated tunnel.
43. The method for determining the identify of a back-up secure tunnel of claim 42 wherein the back-up secure tunnel is formed from two unidirectional tunnels.
44. The method for determining the identify of a back-up secure tunnel of claim 42 wherein the communications network is a virtual private network (VPN).
45. The method for determining the identify of a back-up secure tunnel of claim 42 wherein the back-up secure tunnel is an Internet Protocol Security (IPSec) tunnel.

**SYSTEM AND METHOD TO VERIFY
AVAILABILITY OF A BACK-UP SECURE TUNNEL
ABSTRACT OF THE INVENTION**

A method and system for verifying the availability of a back-up virtual private network IP security (IPSec) tunnel between two network elements by originating a plurality of connection tests between the network elements. The first network element transmits a backup tunnel verification test message to the second network element over the back-up secure tunnel upon receipt of a backup tunnel verification test command. The back-up secure tunnel includes two unidirectional tunnels. The second network element receives the back-up tunnel verification test message over the first back-up unidirectional secure tunnel and transmits a response back to the first network element over the second back-up unidirectional secure tunnel. The number of failures to respond by the second network element to the backup tunnel verification tests performed during an active verification period specified in the backup tunnel verification test command are reported back to the source that initiated the back-up secure tunnel verification test.

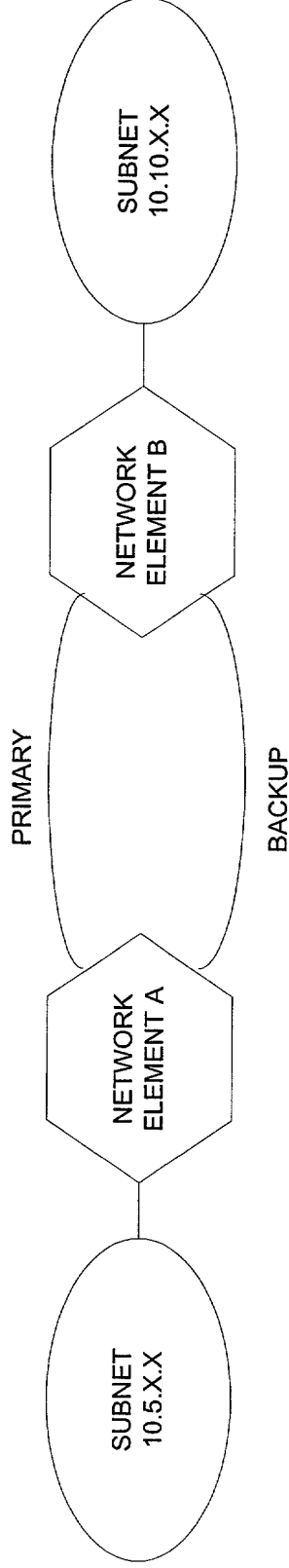


FIG. 1A

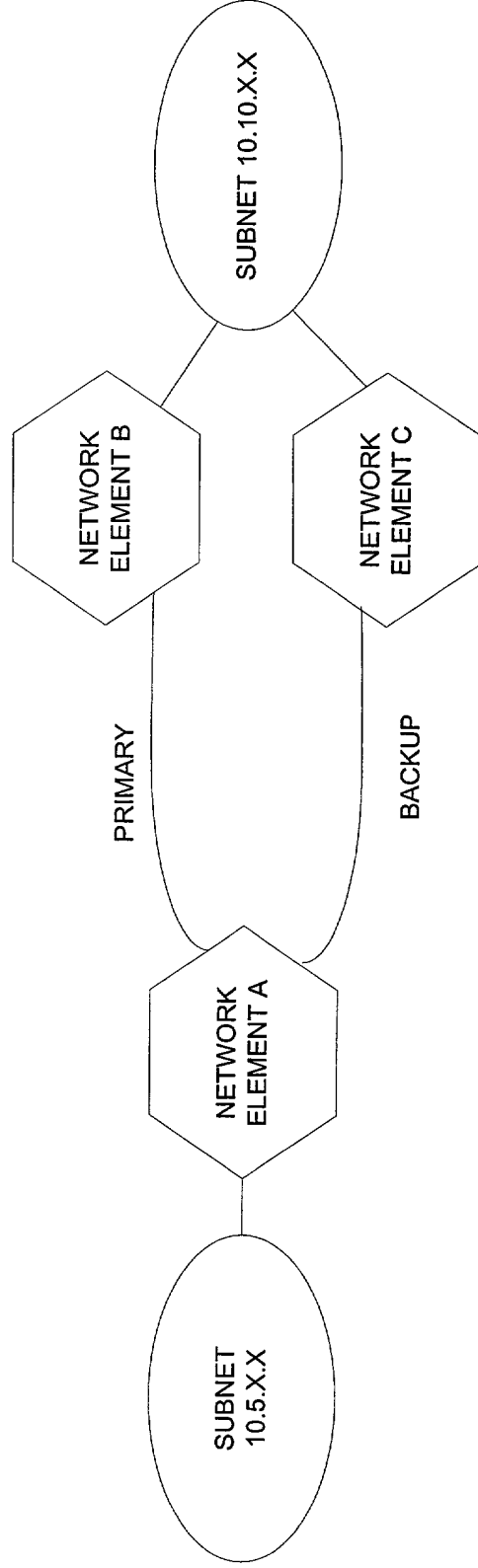


FIG. 1B

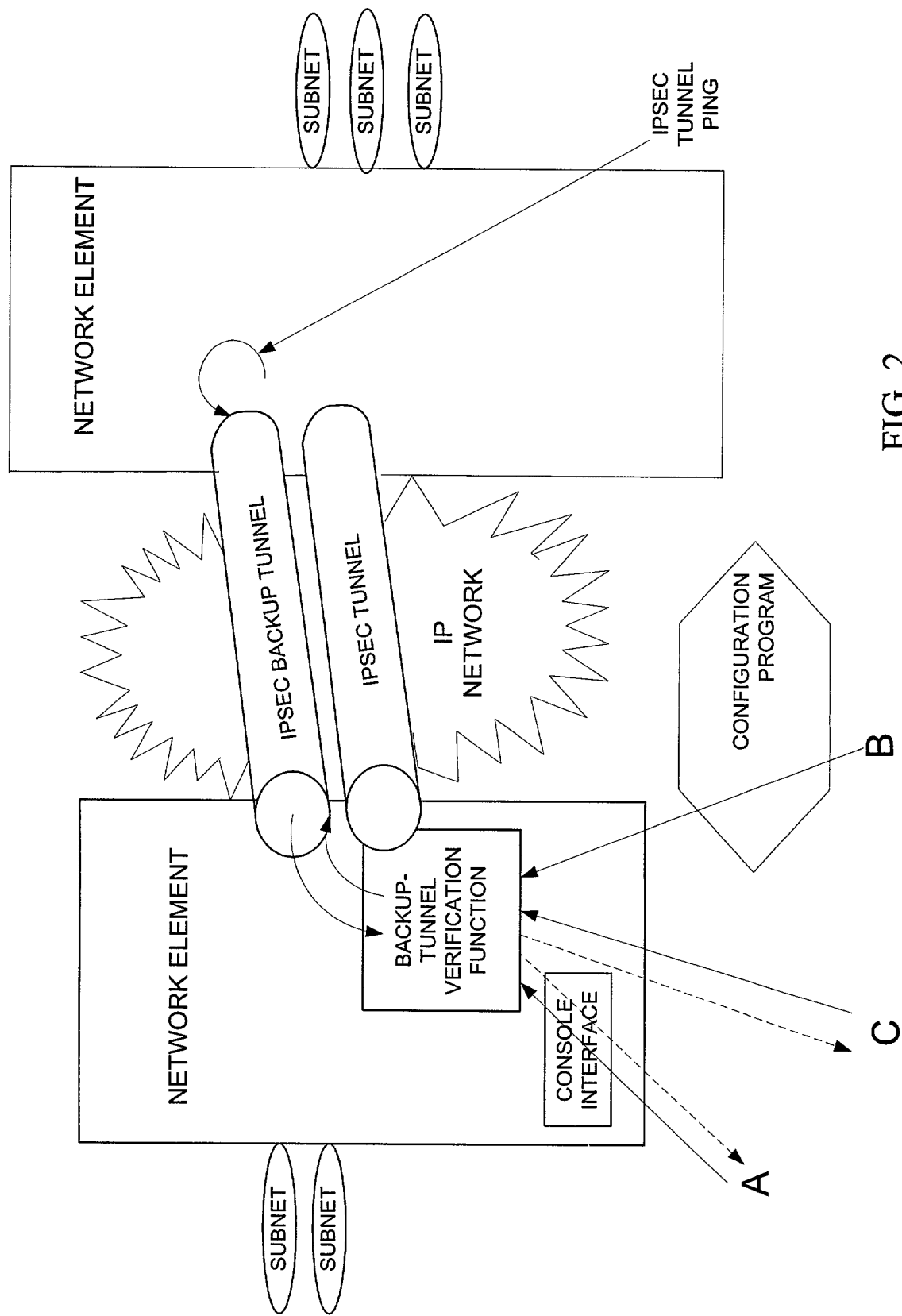


FIG. 2

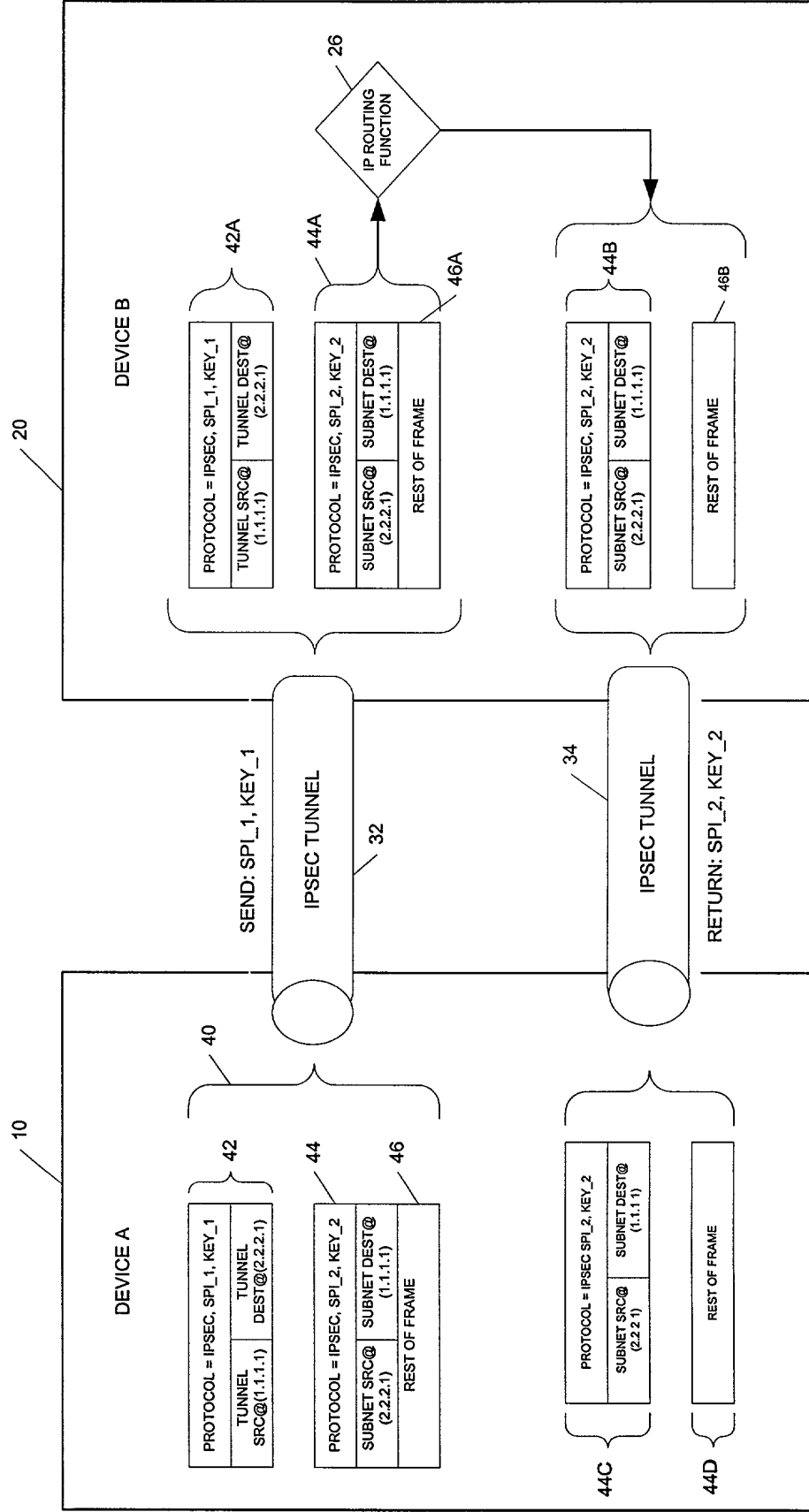


FIG. 5

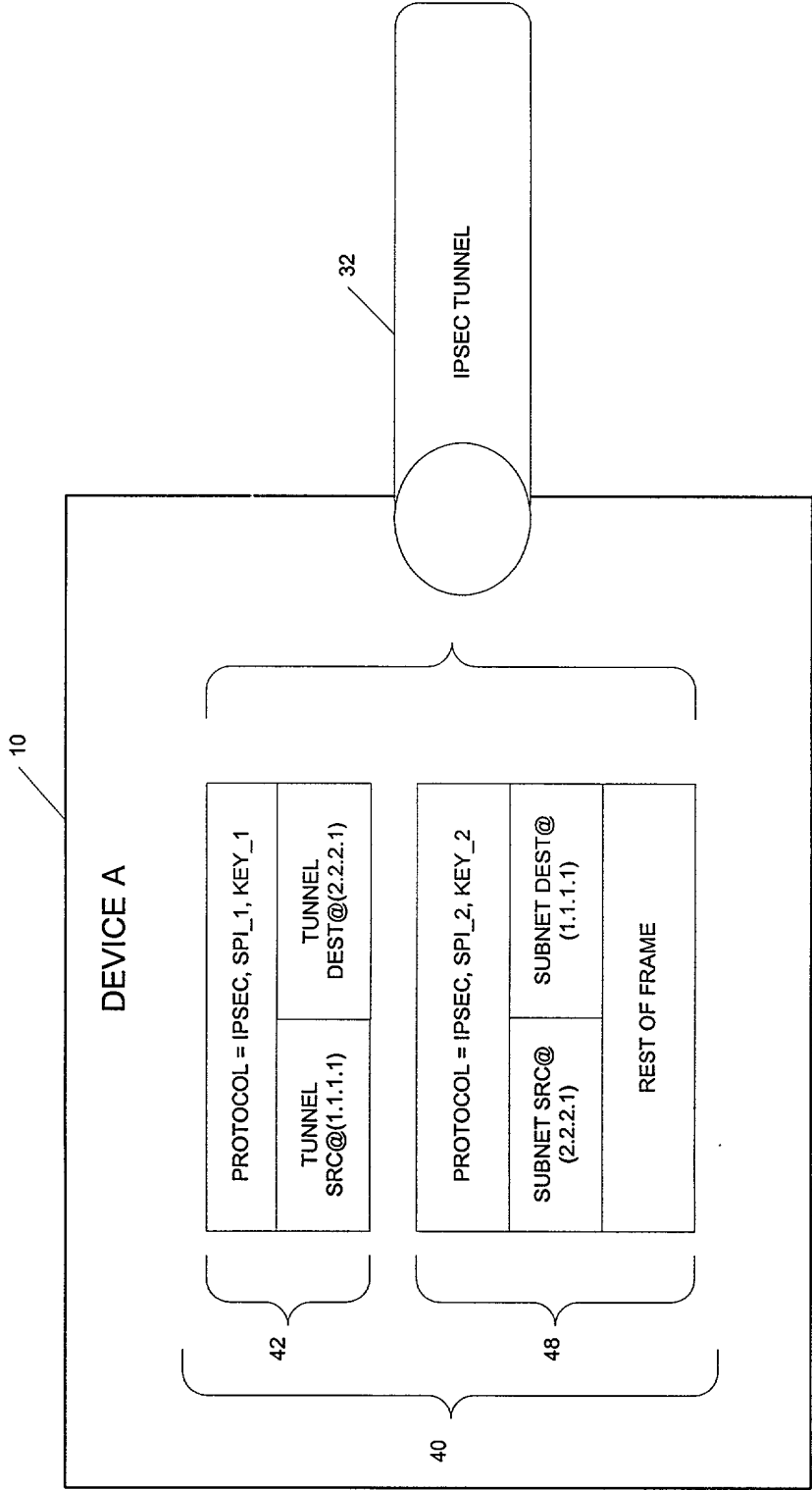


FIG. 6

Figure 1 consists of 12 subplots (a-l) showing the effect of various parameters on the growth rate of *E. coli*. Each plot has 'Growth rate' on the y-axis (0.0 to 1.0) and a parameter on the x-axis. (a) Temperature (°C) from 10 to 40. (b) pH from 4 to 10. (c) Salinity (g/L) from 0 to 20. (d) Oxygen concentration (mg/L) from 0 to 10. (e) Light intensity ($\mu\text{mol photons m}^{-2} \text{s}^{-1}$) from 0 to 100. (f) Nitrogen concentration (mg/L) from 0 to 10. (g) Phosphorus concentration (mg/L) from 0 to 10. (h) Iron concentration (mg/L) from 0 to 10. (i) Zinc concentration (mg/L) from 0 to 10. (j) Copper concentration (mg/L) from 0 to 10. (k) Silver concentration (mg/L) from 0 to 10. (l) Silver concentration (mg/L) from 0 to 10. The growth rate generally decreases as the concentration of the parameter increases, except for temperature and pH which show a peak.

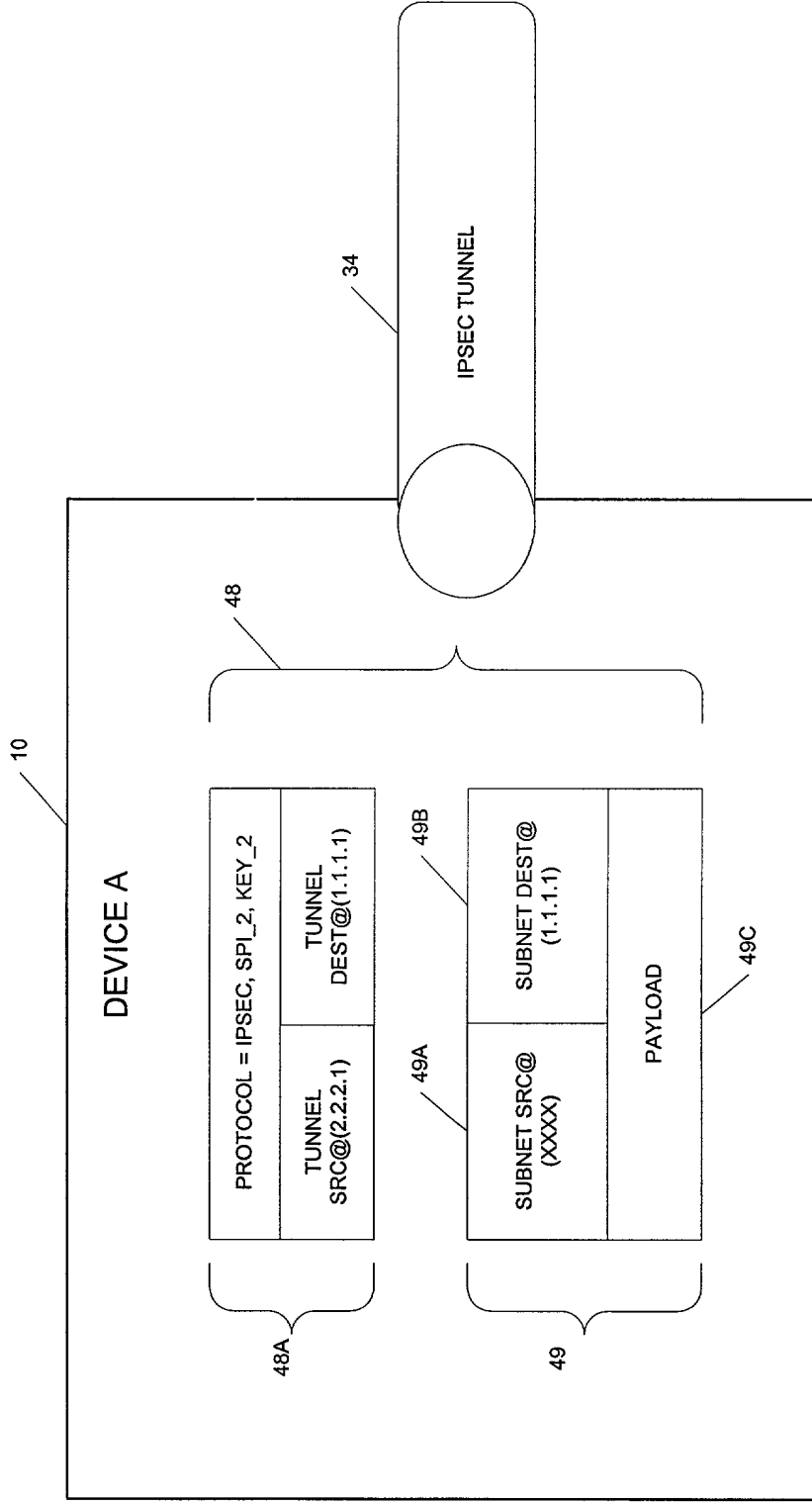


FIG. 7

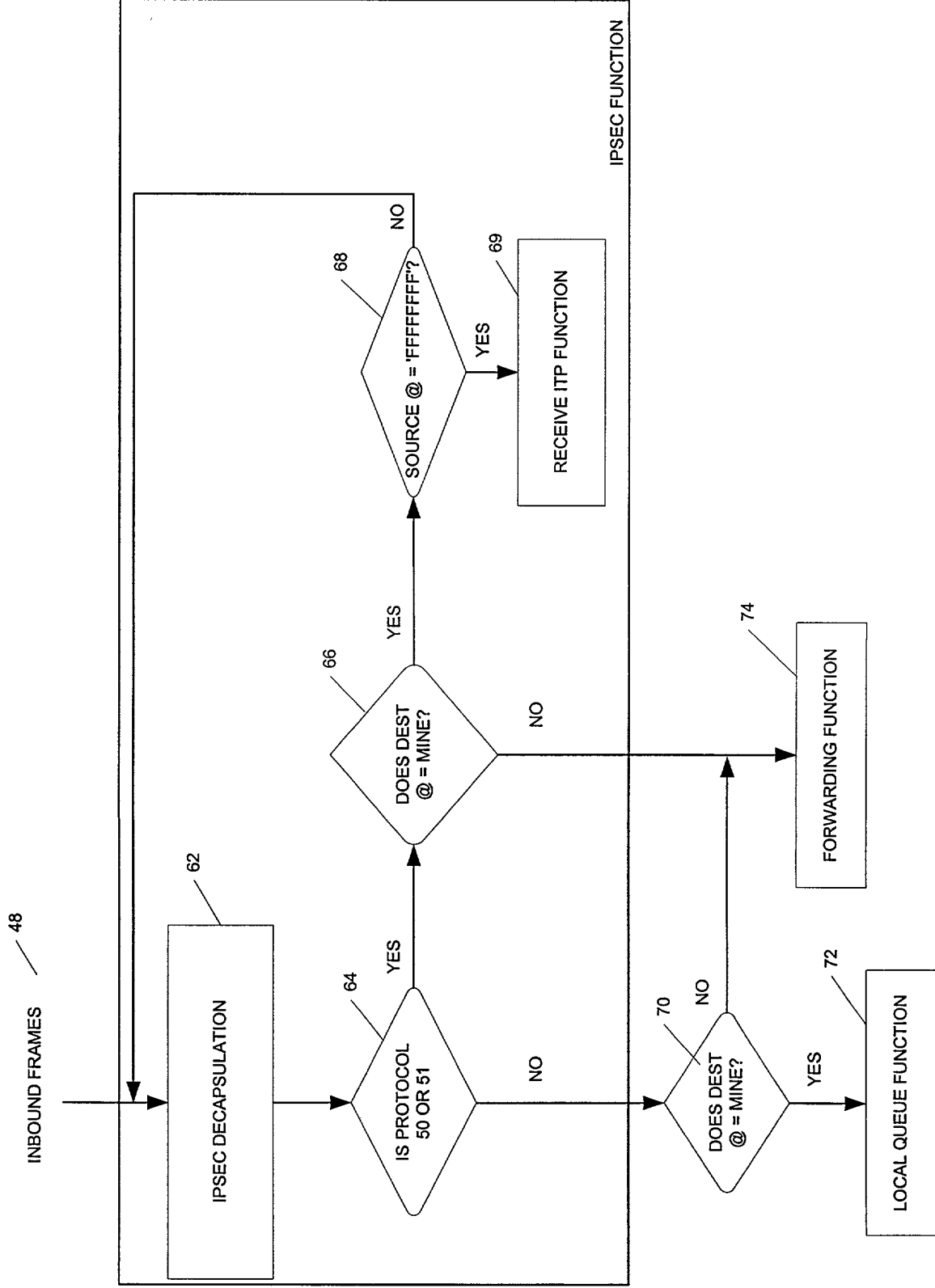


FIG. 8

The diagram illustrates the structure of an IPsec packet, showing nested headers and a payload. The components are as follows:

- Outer Header (40):** Contains the text "SRC IP @, DES IP @, PROTOCOL = IPSEC".
- Inner Header (48):** Contains the text "SPI_1, USING KEY_1".
- Inner Header (49A, 49B):** Contains the text "SRC IP @, DES IP @, PROTOCOL = IPSEC".
- Inner Header (49C):** Contains the text "SPI_2, USING KEY_2".
- Payload:** Contains the text "PAYLOAD:" followed by a list of fields:
 - TIMESTAMP FIELD
 - SEQUENCE NO. FIELD
 - OTHER FIELDS

Brackets on the left side of the diagram indicate the following groupings:

- 40:** Groups the outer header and the inner header (48).
- 48:** Groups the inner header (48) and the inner header (49A, 49B).
- 49:** Groups the inner header (49A, 49B) and the payload.

FIG. 9

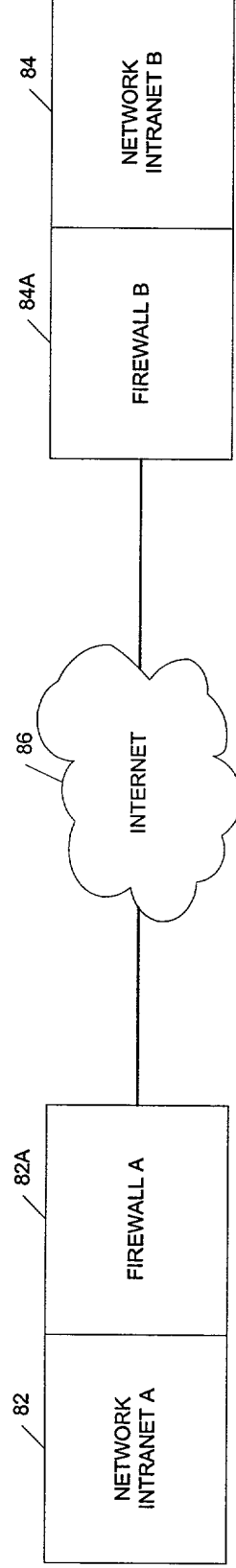


FIG. 10

00203D"644DE960

DEVICE ADDRESS		SPI	ENCRYPTION KEY
SOURCE	DESTINATION		
A	B	SPI-1	KEY_1 = "ABC..."
B	A	SPI-2	KEY_2 = "FG123..."

FIG. 11

**DECLARATION AND POWER OF ATTORNEY
FOR PATENT APPLICATION**

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name; I believe I am an original, first and joint inventor of the subject matter which is claimed and for which a patent is sought on the invention entitled:

System and Method to Verify Availability of a Back-Up Secure Tunnel

the specification of which is identified by the attorney (IBM) Docket Number appearing above.

I hereby state that I have reviewed and understand the contents of the above- identified specification, including the claims.

I acknowledge the duty to disclose information which is material to the patentability of this application in accordance with Title 37, Code of Federal Regulations, §1.56.

I hereby claim foreign priority benefits under Title 35, United States Code, §119 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

Prior Foreign Application(s)

<u>Number</u>	<u>Country</u>	<u>Day/Month/Year</u>	<u>Priority Claimed</u>
---------------	----------------	-----------------------	-------------------------

I hereby claim the benefit (a) under Title 35, United States Code, §119(e) of any U.S. application listed below and identified as a provisional application or (b) under Title 35, United States Code, §120 of any U.S. application listed below and not identified as a provisional application, and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior U.S. application in the manner provided by the first paragraph of Title 35, United States Code, §112, I acknowledge the duty to disclose information material to the patentability of this application as defined in Title 37, Code of Federal Regulations, §1.56 which occurred between the filing date of the prior application and the national or PCT international filing date of this application

Prior U.S. Applications

<u>Serial No.</u>	<u>Filing Date</u>	<u>Status</u>
-------------------	--------------------	---------------

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

As a named inventor, I hereby appoint the following attorneys and/or agents to prosecute this application and transact all business in the Patent and Trademark Office connected therewith:

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